Sediment Transport Modeling off the Northeast Coast of Florida

Gary A. Zarillo
Florida Institute of Technology and Scientific Environmental Applications, Inc., Melbourne, FL
Combining Geological and Numerical Models to Assess the Impacts of Mining Sand Resources on the Inner Continental Shelf of Northeast Florida

Geology of Shelf Sand Ridges

*Origin and Dynamics*

**Numerical Modeling**

- *Strategy*
- *Applications*
- *Results*
Cretaceous Shannon Sandstone – Powder River Basin, WY

Cross-bedded shallow water sandstones (Higley et al. 1997)

Geology of Shelf Sand Ridges

From Tillman 1985

Cross-bedded medium to coarse sand (ridge seds.)

Cross-bedded & rippled, burrowed sands (ridge margin seds.)

Interbedded sands and mud (inter-ridge seds.)

Back-barrier sands, silt, & mud

Basal Peat
Eroded pre-Holocene

Cross-Bedded Shallow Water Sandstones

(Higley et al. 1997)
# Sand Ridges in the Rock Record

**Mesozoic- Cenozoic Stratigraphy**

![Diagram of Mesozoic- Cenozoic Stratigraphy](image)

**From USGS**
Oil Production from Ridge Sandstones

House Creek Field Cumulative Oil Production

Sussex B Sandstone

From USGS
Modern – Ancient Analogues

Cretaceous Period Sand Ridge

Fox Hills Sandstone (Cretaceous Shelf Sand Ridge)

Ravinement surface

Cross-bedded storm unit

Silts and clays (weathered shale)

A6 Sand Ridge
NE Florida Continental Shelf
Transgressive Sand Ridge Deposits – Fox Hills Sandstone
Cross-bedded Storm Unit – Fox Hills Sandstone
Geology of Modern Shelf Sand Ridges

Ancient Sand Ridge

Modern Sand Ridge: A6 NE Florida

See Tillman 1985; Rine et al. 1991 for shelf sand ridge geology
Sand Ridge Origin in a Transgressive Barrier Island Setting

1. BARRIER ISLAND COAST

2. INLET OPENS

3. INLET MIGRATES

4. INLET WANES

5. INLET CLOSED

6. RIDGE DETACHMENT

McBride and Moslow 1991
McBride and Moslow 1991

Shelf Sand Ridges – Florida Examples
Indian River Shoal off East Central Florida Inner Continental Shelf Beach Sand Borrow Area
Sand Ridges/Linear Shoals of the NE FL Study Area
Perspective Views of NE FL Shoals B11/B12

Shoals B12 and B11
Model Grid Boundaries

A4-A6 Model Grid

A8 Model Grid

A9 Model Grid

B11-B12 Model Grid
Spectral Wind-Wave Transformation Model CMS-WAVE Based on a spectral wave energy conservation equation: Considers wind input, shoaling, refraction, diffraction, and dissipation wave-current interaction.

Circulation Model - CMS-FLOW Two-dimensional, finite-volume numerical solution of the depth-integrated continuity and momentum equations: Considers wave-current interaction, advection - diffusion, nonlinear continuity terms, forcing by water level, tidal constituents, flow-rate, wave stresses, and wind.

Sand Transport Model - “LUND” Formulation Considers bed load, suspended load, wave-current interaction, initiation of motion, slope effects, and asymmetric wave velocity.
Coastal Modeling System

CMS-Wave
- Diffraction, Reflection, Run-up, Setup, Overtopping
- Wave Generation, Structures (breakwaters, jetties, groins, etc)
- Nested Grids

CMS-Flow
- Hydrodynamics: Tide, Current, Wind, Rivers
- Wave Info
- Sediment Transport
- Salinity Transport
- Morphology: Morphologic Constraints

Current, Water Level, Morphology Change
Wave Height, Direction, Period, Dissipation, Radiation Stresses
Circulation - Wave Steering Interval

Model Setup

- **Boundary-Forcing Cells**
- **Observation Stations**
- **WIS Stations**
Model Setup – Boundary Time Series

Water Level/ Winds

Tides

Wave Spectra
Storm-Related Wave Events

Maximum Wave Event

Date

Significant Wave Height, m
Peak Period, s

Hsig, m
Period, s
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Wave Model Calibration: NE Florida

Model Wave Height, m

Measured Wave Height, m

$R^2 = 0.93$
Wave Model Calibration for NE Florida

Measure vs. Model Wave Period

Measure vs. Model Wave Direction
Numerical Modeling Strategy

ERDC/CHL Coastal Modeling System Coupled Wave and Circulation Models

- Time advancing runs of 2 years
- Event scale predictions for storm conditions
- Model predictions with/without borrow cuts
- Test single & multiple cuts from potential borrow areas
- Examine potential for modification of sediment transport
## Summary of NE Florida Model Test Cases

<table>
<thead>
<tr>
<th>Model Test</th>
<th>Location</th>
<th>Borrow Cut</th>
<th>Volume (m³)</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>B11_B12 Shoals</td>
<td>None</td>
<td>0</td>
<td>2 years</td>
</tr>
<tr>
<td>Case 2</td>
<td>B11_B12 Shoals</td>
<td>Single</td>
<td>600,000</td>
<td>2 years</td>
</tr>
<tr>
<td><strong>Case 3</strong></td>
<td><strong>B11/B12 Shoals</strong></td>
<td><strong>Multiple</strong></td>
<td>8 million</td>
<td>2 years</td>
</tr>
<tr>
<td>Case 4</td>
<td>A9 Shoal</td>
<td>None</td>
<td>0</td>
<td>2 years</td>
</tr>
<tr>
<td>Case 5</td>
<td>A9 Shoal</td>
<td>Single</td>
<td>1.2 million</td>
<td>2 years</td>
</tr>
<tr>
<td>Case 6</td>
<td>A9 Shoal</td>
<td>Multiple</td>
<td>6 million</td>
<td>2 years</td>
</tr>
<tr>
<td>Case 7</td>
<td>A8 Shoal</td>
<td>None</td>
<td>0</td>
<td>2 years</td>
</tr>
<tr>
<td>Case 8</td>
<td>A8 Shoal</td>
<td>Single</td>
<td>1.2 million</td>
<td>2 years</td>
</tr>
<tr>
<td>Case 9</td>
<td>A8 Shoal</td>
<td>Multiple</td>
<td>9.3 million</td>
<td>2 years</td>
</tr>
<tr>
<td>Case 10</td>
<td>A4-A6 Shoals</td>
<td>None</td>
<td>0</td>
<td>2 years</td>
</tr>
<tr>
<td>Case 11</td>
<td>A4-A6 Shoals</td>
<td>Single</td>
<td>2.8 million</td>
<td>2 years</td>
</tr>
<tr>
<td><strong>Case 12</strong></td>
<td><strong>A4-A6 Shoals</strong></td>
<td><strong>Multiple</strong></td>
<td>18 million</td>
<td>2 years</td>
</tr>
</tbody>
</table>
B11-B12 Model Test Case 3
Predicted Difference in Wave Height

Existing vs. Borrow Cuts: Hurricane Waves

![Map showing net difference in wave height with color scale and markers B11 and B12.]
Event Scale Topographic Change

Deposition: Lower Shoreface

Erosion: Upper Shoreface

Hurricane Floyd 1999

Net Change (m)

-0.50
-0.40
-0.30
-0.20
-0.10
-0.00
-0.10
-0.20
-0.30
-0.40
-0.50

0
1
2
3
4
5
KILOMETERS

0
Model Predictions in the Littoral Environment

Numerical Recording Stations

Depth, m
27.0
24.0
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0

B11
B12
Predicted Annualized Net Littoral Sand Transport

Negative values indicate south-directed littoral sand transport.
Shoal A6: Model Test Case 12

Federal Limit

Shoreline

Sand Borrow Cuts Shoal A8
Predicted Event Scale Sand Transport

Depth, m

- 25.0
- 22.5
- 20.0
- 17.5
- 15.0
- 12.5
- 10.0
- 7.5
- 5.0
- 2.5
- 0.0

Surfzone

St. Augustine Inlet
Predicted Topographic Change – 24 Months at Shoal A6
(Predicted Topographic Change Over Ridge Crest +/-1 m)

A6 Shoal Crest

No Sand Borrow Excavations
Predicted Morphologic Change over Borrow Excavations
(24-month model run A6 Shoal NE Florida Shelf)
Predicted Difference: A4 – A6 Shoals
Annualized Net Sand Transport in the Littoral Zone
• Sand Ridges of NE Florida Continental Shelf are consistent with the sand geological model having clean sand units at the crest reworked and maintained by storms

• Influence of the borrow cuts is at the event scale due to passing storms and associated long period waves

• Along the NE Florida shoreline the influence of large borrow cuts is detectable but small compared to the annual sand budget and natural variability
Acknowledgments

BOEMRE

U.S. Geological Survey

Florida Geologic Survey

